Taking Phosphor Investigation to the Next Level with SEM-CL/EDX

L.I.D.J. Martin[1,2]*, K. Korthout[1,2], D. Poelman[1,2], P.F. Smet[1,2]
[1]LumiLab, Department of Solid State Sciences, Ghent University, Ghent, Belgium
[2]Center for Nano- and Biophotonics (NB-Photonics), Ghent University, Ghent, Belgium
*Lisa.Martin@UGent.be

Luminescent materials, also known as phosphors, are an essential component of white light emitting diodes (LEDs). White LEDs consist of a blue emitting LED chip and one or more phosphor materials which convert part of the blue light to longer wavelengths. In order to mimic the spectrum of a black body radiator as closely as possible, luminescent materials showing broad emission bands are used. For these phosphors there is a strong correlation between their composition and structure on the one hand and their optical properties on the other hand [1].

A perfect means for microscopic investigation of these materials is provided by SEM-CL/EDX. A scanning electron microscope (SEM) is capable of producing images with high spatial resolution, showing the morphology and average grain size of the phosphor powders. With the addition of an energy-dispersive X-ray detector (EDX) local composition can be studied simultaneously. Since dopant concentration is often limited to 0.1% to 1%, EDX analysis only allows a qualitative interpretation for presence and dispersion of the dopants.

Studying cathodoluminescence (CL) in the same microscope strongly extends the analytical power of the measurement system: by coupling a CCD-based spectrometer to the SEM, it is possible to match a local emission spectrum to a nanometer sized area (Fig. 1). Since small variations in dopant concentration and particle morphology have an influence on intensity and shape of the CL spectrum, differences in local spectra show where to look for particularities. Linking these spectra to the EDX results can confirm these local variations in dopant concentration.

Another advantage of SEM-CL/EDX, in addition to its high spatial resolution, is its ability to obtain more detailed depth-resolved information by varying the electron-beam energy [2].

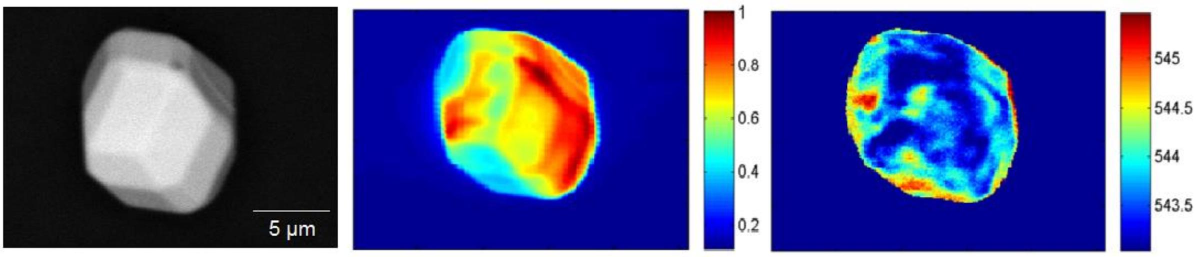

Figure 1: Backscattered electron image (left), normalized total CL intensity (center) and emission barycenter in nm (right) derived from a spectrally resolved CL mapping of $Lu_3Al_5O_{12}$:Ce at -25°C.

Correlating structural, compositional and luminescent information allows for identification of non-uniform doping or impurity phases, which can be used to improve synthesis methods and possibly also the overall performance of the phosphors [3].

[1] D. Poelman, and P.F. Smet, Physica B. **439**, 35-40 (2014).
[2] B.G. Yacobi, and D.B. Holt, Journal of Applied Physics. **59**, R1-R24 (1986).
[3] P.F. Smet, J. Botterman, A.B. Parmentier, and D. Poelman, Optical Materials **35**, 1970–1975 (2013).